theory, objections based upon those observations and upon several scientific principles.

"After some very interesting considerations on the subject and a number of remarkable quotations, it concludes by proposing an entirely new theory for the explanation of these phenomena.

"According to the author the shooting stars are ball lightnings which abound in the upper regions of the atmosphere and under certain conditions their number all over one and the same region is so considerable, as to present the appearance of a shower.

"When these lightnings are formed in the lower regions of the atmosphere or in the case of their descending far down in the same, they originate the so-called bolides; and when the ball lightning darts through a cloud or through air impregnated with substances lifted up from the surface of the soil and scattered in the atmosphere through cyclones and hurricanes or volcanic eruptions, their effect is to unite all those substances into one single mass, thus forming the meteorite or aerolite.

"Ball lightnings and rains of ball lightnings are not of frequent occurrence in the atmospheric strata immediately above the surface of the earth, still there are instances of both kinds of phenomena."

BESTIMMUNG VON PARALLAXEN DURCH REGISTRIR-BEOBACHTUNGEN AM MERIDIANKREISE, VON DR. J. C. KAPTEYN.

By Professor Lewis Boss.*

A more exact knowledge of the sun's motion in space is a pressing requirement in preparing the way for the stellar astronomy of the future. Up to the present time all our attempts to regard the stars in a comprehensive way, as situated in space of three dimensions, have been either rudely tentative, or merely speculative. To some extent this must continue to be the position of generalization in stellar astronomy for some time to come. Yet it is plain to be seen that stellar astronomy in its true geometrical relations is gradually advancing in importance with sure steps and continuously, toward the point when it must become the most fruitful as well as the most imposing object of research

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in the entire range of science. One step in this advance has been the determination of the direction of solar motion, though no one has yet by any means exhausted the material upon this problem which is now actually available. A more important step will be a reasonably accurate determination of the velocity of the sun's motion in some known unit of length. Having accomplished this we shall have the base line for stellar investigation.

There are two important classes of astronomical measurements which, in connection with facts of which we already have sufficiently approximate knowledge, will lead to a satisfactory determination of the velocity of the sun relatively to some thousands of stars which are nearest it.

First, there are the spectroscopic measurements of the velocity of that component of the motion of individual stars which is in the direction of the line of sight, toward or from the sun. In this work the Greenwich Observatory has made a most important and praiseworthy beginning. Recently, Professor VOGEL, of the Potsdam Observatory, has shown that a very high degree of precision is attainable in this class of measurements. We are permitted to hope that his example will stimulate those who have powerful optical appliances at command to extend these measures so as to include, at least, all the stars visible to the unassisted eye which have motions of 10″ per century or more. When that is accomplished it is not at all improbable that we shall be able to determine the velocity of the sun's way, relatively to the stars considered, with greater precision than we now know the velocity of the earth in its orbit.*

This knowledge can be reached, however, in another way. If we take any large number of stars distributed over the celestial sphere it is possible to determine the angular velocity of the sun's way as seen from the mean distance of the stars considered; provided the ratio of the greatest to the least distance of the stars under treatment is not too large, or that the mean distances of groups of the selected stars in different quarters of the sky do not greatly vary, or, still better, provided we have some well-grounded criterion by which to judge of the relative distances of the stars considered. At present it might be regarded a hopeless task to accumulate satisfactory measures of the individual distances of the thousands of stars which ought to be taken into account in a re-

* I understand that the great telescope of the Lick Observatory is to be devoted to this research in the immediate future.

search of this kind. It happens that we are actually in possession of a very plausible hypothesis as to the proper criterion of judging relative distances of stars. This criterion consists simply in the supposition that in the mean of a large number of stars the distances are inversely proportional to the apparent thwart motions of the stars—the proper motions. Thus we are fairly entitled to say as the result of mathematical investigations that the stars having apparent proper motions of 10″ per century are four times as far from the sun as are the stars which have a proper motion of 40″. Professor T. H. SAFFORD was one of the first to call attention to this fact by specific calculations in a paper published seventeen years ago in Proceedings of the American Academy of Sciences (Vol. X, p. 82 ff). His conclusion that in studying the solar motion the distances must be assumed as inversely proportional to the proper motions has been substantially confirmed, although it is not known that the evidence has been collected in a systematic form,—evidence which may easily be gathered from the most important researches upon the motion of the sun that have appeared during the last twenty years. It is indeed probable that this criterion of distance may ultimately require some modification. It already appears probable that the stars with the larger proper motions are relatively nearer the sun than is indicated by the law of inverse ratio of proper motion. Thus it might be inferred that the sun is situated in a cluster of small stars slightly and gradually condensed toward the center. Still other modifications of this law are indicated,—but too uncertainly for profitable comment at the present time.

Evidently when stars are considered in classes of brightness involving thousands in each class, there may be a rough correspondence of distance with apparent brightness. There would also be a rough correspondence in the average of proper motions, such that the brighter stars, in the mean of a very large number, would have larger proper motions. It appears inadvisable, therefore, to introduce a factor representing the feeble testimony of brightness as to distance into the criterion for relative distances of the stars.

It should by borne in mind that on the hypothesis that the directions of stellar motion are equally distributed (at random) over the surface of the sphere we see on an average nearly four-fifths ($\frac{\pi}{4}$) of the total motion; and not quite 14 per cent. of the stars would exhibit less than one-half the total motion.

It becomes evident, therefore, that a fair degree of approximation as to the real distances of stars considered in large groups may be derived from the measurement of a comparatively small number of parallaxes. At the same time, if these measurements are distributed over the widest practicable range of proper motion we may derive additional testimony of some value as to whether the inverse ratio of proper motion affords in the mean a safe criterion of relative distance. For this purpose one would select, say, five hundred stars having proper motion greater than 25″ per century. If, then, it were found, for example, that the average annual parallax is one-tenth of the proper motion, we should possess a ready means of assigning with some degree of confidence the mean distance of any large number of selected stars having nearly the same apparent proper motions. It is this far-reaching application of our knowledge of annual stellar parallax in individual cases that should stimulate interest in the determination far beyond that which would attach to the problem in its direct relations.

Prof. Dr. KAPETYN has shown in what way a large number of observers, already in possession of the requisite instrumental equipment, may produce important contributions in the interest of these stellar problems which in the foregoing paragraphs have been merely indicated in their surface relations. The method for determination of parallax adopted by Professor KAPTEYN has not only the very great advantage in a problem of such delicacy as this of variation in method, but it also appears to have produced highly trustworthy results at a comparatively small expenditure of labor. He has determined the parallaxes of fifteen stars selected from ARGELANDER'S well known list of two hundred and fifty stars of large proper motion (*Bonner Beob.*, *Bd.* VII, *Theil* I). For this purpose he used his vacation time and employed the meridian circle of the Leyden Observatory. The adopted method was to determine differential parallaxes by means of differential transits near the two extremes of parallactic displacement in Right ascension.

The method of differential transits had been tried in the practiced hands of Dr. AUWERS with the Equatorial of the Gotha Observatory in the years 1863–1866, and the result was not such as to encourage its further employment. But the parallaxes which Dr. BELOPOLSKY had deduced from the transit observations of WAGNER afforded evidence that the use of meridian transits for

this research is full of promise. The observations of WAGNER were not intended to be used for this purpose, and there was, therefore, no systematic arrangement of comparison stars. The probable errors were in consequence large; yet the results seemed to indicate that this method is remarkably free from sources of constant error,—a conclusion which the observations of Professor KAPTEYN appear to have confirmed in a remarkable degree.

The arrangement of Professor KAPTEYN'S observations was quite simple. It consisted in selecting two comparison stars of small proper motion (and presumably of small annual parallax), and arranging this selection in such a way that the mean of the declinations of the comparison stars would fall very near that of the star whose parallax was to be determined. Since the interval in declination between the two comparison stars in each case was also small, the requirement was practically reduced to a question of well made pivots, kept thoroughly clean, with careful handling of the instrument, and the greatest attainable perfection in the registry of transits. The actual positions of the stars and the exact value of the instrumental constants, thus became considerations of minor importance. In order to eliminate the possibly injurious influence of imperfectly determined proper motions, the series of observations were arranged so as to begin and end at the same season. The epochs of observation were: 1885 April, 1885 December, 1886 December, and 1887 April.

The most troublesome source of systematic error to be feared arises from possible variation of the personal habit of registry as between stars of different degrees of brightness. Evidently, if this personal error of the observer remains constant throughout the series, no appreciable error could arise from this source. But this constancy of habit could by no means be assumed, and probably does not obtain with the great majority of observers. Professor KAPTEYN employed wire-gauze screens in front of the objective not only for the purpose of reducing the images of parallax and comparison star to nearer equality of brightness, but also to determine the personal equation for magnitude at the several epochs of observation. The outcome of this part of the investigation was that in the first period the faint stars were observed too late by $0^s.0005$ for one magnitude; in the second series, too early by $0^s.0042$; in the third, too early by $0^s.0068$; and in the fourth, too early by $0^s.0045$ for each magnitude. Professor KAPTEYN concludes that whatever change there may have been,

took place between the first and second series. He had been out of practice in transit observations for seven years previous to this undertaking, and it is natural to suppose that his personal habit of observing transits might have been a little uncertain at first. At any rate, it appears that the assumption that his personal error remained invariable throughout the series would not have made a difference of more than $0''.01$ in the deduced parallax in any case.

The probable error of transit for a single thread was found to be only $\pm 0^s.0404$, and the actual probable error of a comparison depending on about twenty threads for each star came out $\pm 0^s.0168$, or $\pm 0^s.0158$ by the use of weights,—leaving less than $\pm 0^s.01$ for the "day-error," or general instrumental error. None but the most careful and skilled observers can hope to attain these low limits of error.

The tables of detailed reductions for each comparison star bear ample testimony to the care and thoroughness with which the computations have been made. In a research in which the final quantity to be ascertained is very nearly, and in many cases quite, of the order of the probable error, only the most rigorous computations serve to bring out the value of good observations.

The following table contains a summary of Professor KAPTEYN'S results:

Star.	Parallax. ″	P. E. ″	Proper Motion. ″
Arg. 81 pr.	+ 0.074	± 0.027	1.69
θ Urs. Maj.	+ 0.052	± 0.026	1.11
Arg. 85	+ 0.064	± 0.022	0.79
20 Leon. Min.	+ 0.062	± 0.029	0.69
Arg. 89	+ 0.176	± 0.024	1.43
Arg. 94	+ 0.101	± 0.026	0.89
Arg. 95	+ 0.038	± 0.027	0.27
Lal. 20670	— 0.011	± 0.029	0.30
Arg. 104	+ 0.428	± 0.030	4.75
Arg. 105	+ 0.168	± 0.027	4.40
Arg. 110 sq.	+ 0.030	± 0.027	0.64
Arg. 111	+ 0.016	± 0.032	0.67
Groomb. 1830	+ 0.139	± 0.026	7.05
Arg. 114	— 0.038	± 0.042	0.69
Arg. 119	+ 0.056	± 0.034	0.33

While Professor KAPTEYN contends that with the same expenditure of labor one may attain to nearly as small a probable error by this method of differential transits as by the use of the heliometer, he also concedes in his closing remarks that this method is best adapted to the investigation of parallax by the wholesale, rather than to that of individual parallaxes. He outlines a very attractive program whereby a few observers, in a comparatively short time, would be able to determine the parallaxes of all the stars of the fifth magnitude or brighter. According to the Uranometria Argentina these, including both hemispheres, number 1212. Assuming that, at the two extremes of parallax in Right Ascension, it is possible on the average to secure an available factor of 0.89 in the observations (measuring 1.76π in each case), eight observations at each extreme would give for the probable error of each parallax, $\pm 0''.052$. All parallaxes of $0''.20$ or greater would be certainly detected; 90 per cent. of those greater than $0''.15$ would be revealed; and of those which come out by observation $0''.10$ or more, three-fourths would turn out to have parallaxes of $0''.10$ or greater. But, as he maintains, the important result would be that the *mean parallax* of each class (order of magnitude) would be determined with great exactness.

There seems to be nothing unreasonable, or unattainable, in the enthusiastic picture which Professor KAPTEYN presents. In the present state of stellar astronomy, it might be suggested that the stars for such a *Parallax-Durchmusterung* ought not to be selected according to their magnitudes, but according to their proper motions. Let the 1000 stars having largest proper motions be selected for this proposed investigation. If such an investigation were carried on with the vigor and skill which is manifest in the work of Professor KAPTEYN here under consideration by four observers, two in each hemisphere, there is scarcely a doubt but that the necessary observations could be completed on a liberal scale within from six to ten years, and that the results would be of inestimable value in founding the stellar astronomy of the future.

In selecting these stars having large proper motions, it might be well to leave out all those of the fifth magnitude or brighter. These would be but a small fraction of the whole; and there is not much doubt that more reliable results for these brighter stars would be attainable by the use of the heliometer. The stars fainter than the ninth magnitude should be attended to by pho-

tography. In selecting the comparison stars for use with the parallax stars, care should be exercised, so far as possible, to employ no stars for comparison that have a sensible proper motion. Furthermore, the magnitudes of the comparison stars should be as nearly as possible the same as those of the respective parallax stars. For stars below the 6.5 magnitude these conditions would not be difficult of attainment; for brighter stars the difficulty would increase very rapidly with the magnitude, and this constitutes sufficient reason for turning those stars over to the heliometers. With such an arrangement of comparison stars and with no observing appliances further than those which are already available, we appear to have the means of attacking the general problem of star-parallax more effectively than ever before. It would be difficult to conceive of a method which offers better security against the influence of systematic error.

The work of Professor KAPTEYN well illustrates the possibility of putting new life into a hackneyed subject without the aid of startling novelties either in the details of methods, or in the apparatus employed.

OBSERVATIONS OF THE DARK TRANSIT OF *JUPITER'S* THIRD SATELLITE ON AUGUST 20, 1891, AT WINDSOR, NEW SOUTH WALES.

BY JOHN TEBBUTT, F. R. A. S.

The times of the various phases are local sidereal.

h. m. s.

18 33 34; the satellite had advanced considerably on the disc of its primary and was visible as an oval dark spot on the north edge of one of the slender belts in the south equatorial zone. The major axis of the oval was parallel to the belt. The satellite was not nearly so dark as its shadow, which was also visible.

18 50 59; satellite still visible.

19 24 59; it was now at about mid-transit, and the dark phase had slightly increased in depth.

20 3 59; the preceding observations were made with the 4½-inch equatorial and a power of 120. I was now enabled to turn the 8-inch telescope on the planet, and with a